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Paleomagnetic analysis of the Scottsville Mesozoic rift basin, Virginia: implications for regional geologic history

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Paleomagnetic analysis of the Scottsville Mesozoic rift basin, Virginia: implications for regional
geologic history

A thesis submitted in partial fulfillment of the requirement
for the degree of Bachelor of Science in Geology from
The College of William and Mary

by

Nathan Charles Keithline

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Paleomagnetic analysis of the Scottsville Mesozoic rift basin, VA: implications for regional geologic history

A thesis submitted for the partial fulfillment of the requirements for the degree of Bachelor of Science in Geology from The College of William and Mary in Virginia

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Nathan C. Keithline

Williamsburg, Virginia

Table of Contents

<i>List of Figures</i>	2
<i>List of Tables</i>	3
<i>Abstract</i>	4
<i>Introduction</i>	5
<i>Background</i>	11
<i>Paleomagnetism</i>	11
<i>Geologic Setting</i>	12
<i>Methods</i>	20
<i>Field Work</i>	20
<i>Lab Work</i>	22
<i>Results</i>	25
<i>Siltstones</i>	25
<i>Conglomerate test</i>	29
<i>Fold test</i>	29
<i>Diabases</i>	32
<i>Discussion</i>	34
<i>Future Work</i>	37
<i>Conclusion</i>	38
<i>Acknowledgements</i>	39
<i>References</i>	40

List of Figures

<i>Figure 1.</i>	<i>Tectonic reconstruction of Pangea.....</i>	<i>6</i>
<i>Figure 2.</i>	<i>Map of North American Mesozoic rift basins.....</i>	<i>7</i>
<i>Figure 3.</i>	<i>Regional map of Virginia Mesozoic rift basins.....</i>	<i>9</i>
<i>Figure 4.</i>	<i>Schematic of thermal remanent magnetization.....</i>	<i>10</i>
<i>Figure 5.</i>	<i>Schematic of detrital remanent magnetization.....</i>	<i>10</i>
<i>Figure 6.</i>	<i>Geologic map of the Scottsville basin.....</i>	<i>14</i>
<i>Figure 7a.</i>	<i>Field photograph of conglomerate outcrop.....</i>	<i>15</i>
<i>Figure 7b.</i>	<i>Field photograph of sandstone outcrop.....</i>	<i>16</i>
<i>Figure 7c.</i>	<i>Field photograph of diabase outcrop.....</i>	<i>17</i>
<i>Figure 8a.</i>	<i>Bouguer anomaly contour map in the Scottsville basin.....</i>	<i>18</i>
<i>Figure 8b.</i>	<i>Bouguer anomaly cross-sections across Scottsville basin.....</i>	<i>19</i>
<i>Figure 9.</i>	<i>Sample drill cores from diabase and siltstone.....</i>	<i>21</i>
<i>Figure 10a.</i>	<i>Lab photo of AGICO JR-6A spinner magnetometer.....</i>	<i>23</i>
<i>Figure 10b.</i>	<i>Lab photo of SI-4 AF demagnetizer.....</i>	<i>24</i>
<i>Figure 11.</i>	<i>Map of sample locations from Scottsville basin.....</i>	<i>26</i>
<i>Figure 12.</i>	<i>Paleomagnetic data from siltstone samples.....</i>	<i>28</i>
<i>Figure 13.</i>	<i>Paleomagnetic data from conglomerate samples.....</i>	<i>30</i>
<i>Figure 14.</i>	<i>Results from fold test analysis.....</i>	<i>31</i>
<i>Figure 15.</i>	<i>Paleomagnetic data from diabase samples.....</i>	<i>33</i>
<i>Figure 16.</i>	<i>Siltstone and diabase VGP's superimposed on APWP.....</i>	<i>36</i>

List of Tables

<i>Table 1.</i>	<i>Results from paleomagnetic analysis from all samples.....</i>	<i>27</i>
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Abstract:

The Scottsville basin forms one of the westernmost Mesozoic rift basins in Virginia. The basin lies ~25 km SW of Charlottesville, VA astride the transition zone between the Eastern Blue Ridge and Western Piedmont geologic provinces. The ~110 km² basin is a half-graben bounded by a normal fault to the northwest, and unconformably overlies phyllitic rocks of the Piedmont on its southeast margin. Sedimentary rocks in the basin range from boulder conglomerates to sandstone and siltstone red beds and are sourced primarily from the Proterozoic units of the Blue Ridge. NNW striking diabase dikes associated with the Central Atlantic Magmatic Pulse (CAMP) crosscut the sedimentary strata. The purpose of this research was to conduct paleomagnetic analysis on rocks in the basin to better understand the geologic history of the Scottsville basin and the Atlantic rift margin. Paleomagnetic data from conglomerates, siltstones, and diabases sampled across the Scottsville basin indicate post-deposition, post-deformation Middle Jurassic (160-180 Ma) magnetization ages of sedimentary rocks in the basin, contrasted with a primary depositional Late Triassic (210-220 Ma) magnetization age observed in rocks in other proximal rift basins, including the Danville, Taylorsville, and Newark basins. A possible explanation for this later magnetization age is a chemical remagnetization associated with fluid intrusion associated with the late stages of Pangea rifting.

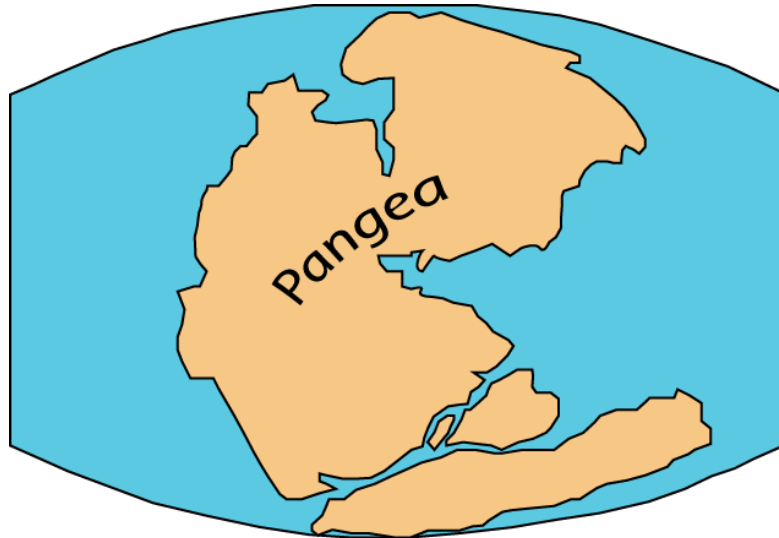
Introduction:

The theory of plate tectonics was one of the greatest advances in geology during the 20th century. The movement of Earth's lithospheric plates is responsible for forming and breaking apart continents, building the highest mountain ranges, and forming the ocean basins. Indeed, understanding how these plates move is critically important to studying Earth's geologic history. Quantifying the current movement of these plates has become straightforward with the invention of GPS; however, reconstructing the tectonic history of Earth is more challenging, as the GPS instrumental record only exists for the last 40 or so years.

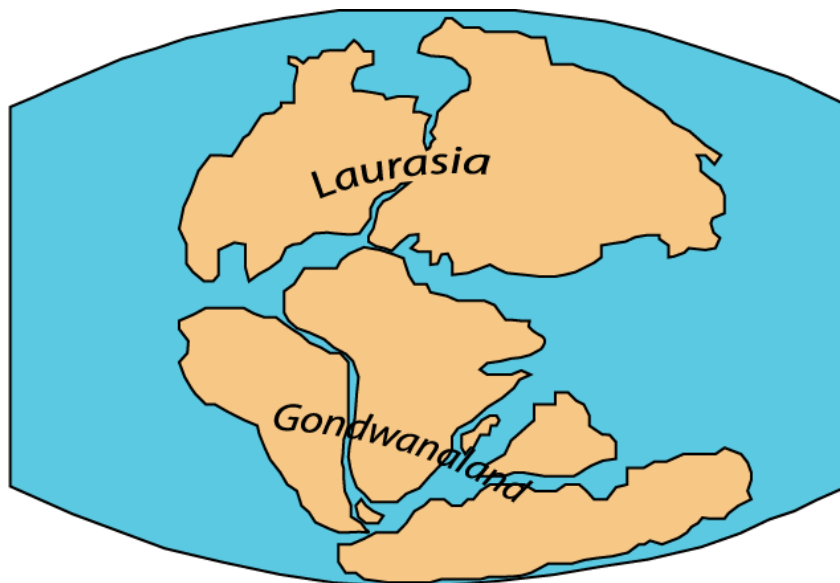
Paleomagnetic analysis is a technique that allows geologists to gain understanding about the history of a rock or area by studying its remnant magnetic signature. When a rock containing magnetic minerals is formed, it can record the Earth's magnetic field at the time and place of its formation, either in the orientation of the individual magnetic grains or the magnetic moment of the rock itself (Cox and Hart, 1986). The analysis of these remnant magnetic signatures can be used to reconstruct the position of plates relative to the magnetic pole, and consequently, their relative locations throughout Earth's dynamic history.

The Mesozoic Era (ca. 250-65 Ma) was a dynamic time period in Earth's tectonic history. Large scale rifting during the Triassic and Early Jurassic led to the breakup of Pangea and the formation of the Atlantic Ocean (Withjack et al., 1998) (Fig. 1). This rifting generated sedimentary basins across eastern North America from Nova Scotia to South Carolina and beyond (Fig. 2). The continental sedimentary rocks and igneous dikes that formed in these basins are collectively known as the Newark Supergroup

(Weems and Olsen, 1997). These rocks are important because they record the nature and timing of the movement of the North American tectonic plate throughout the early Mesozoic (LeTourneau, 2003).



Late Permian



Late Triassic

Figure 1 – Tectonic reconstruction of rifting of Pangea during the Late Permian (~250 Ma) to the Late Triassic (~200 Ma).

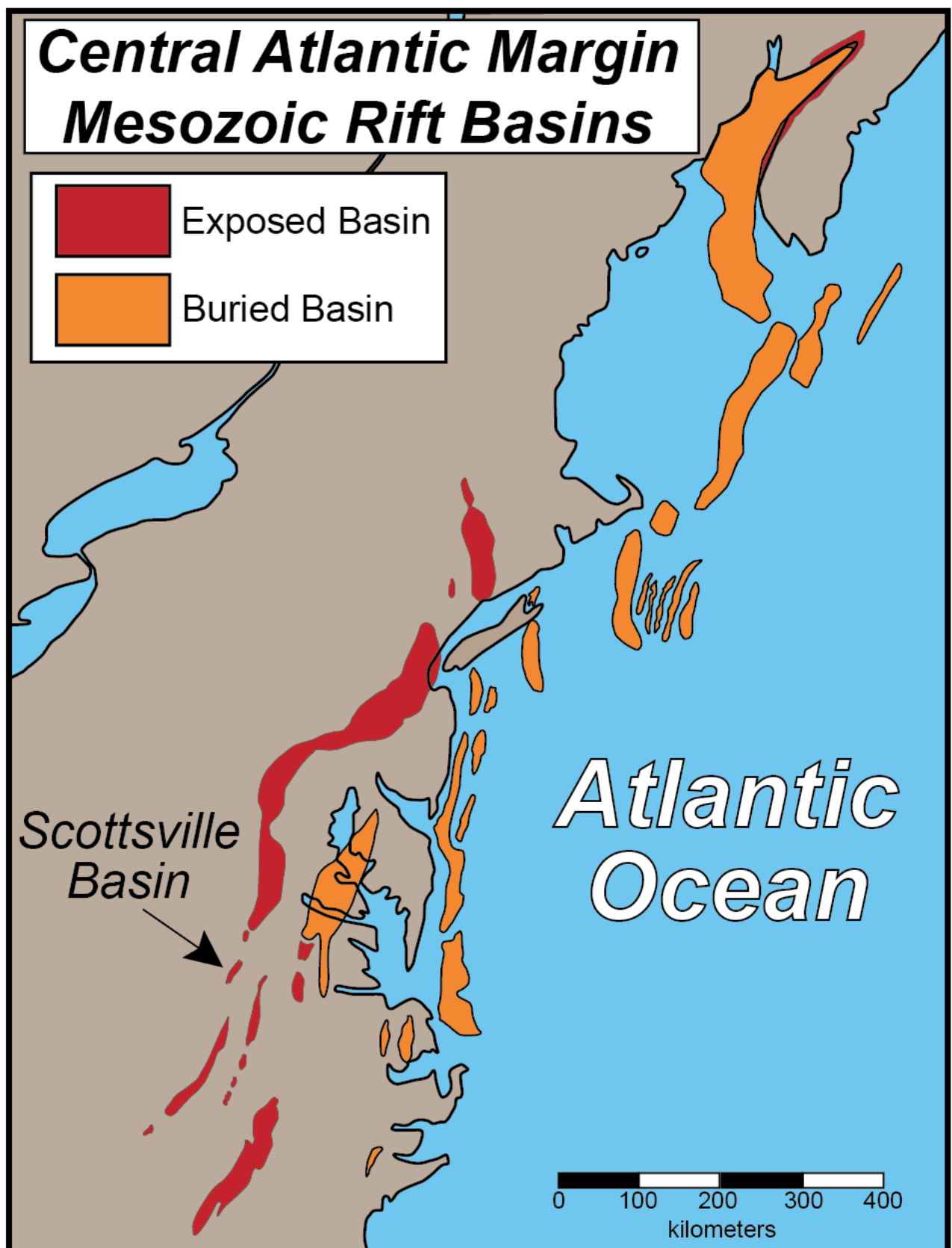


Figure 2 – Map of modern eastern North America and exposed (in red) and buried (in orange) Mesozoic rift basins.

The Scottsville is one of the 11 Mesozoic rift basins exposed in Virginia and is located near the boundary between the Eastern Blue Ridge and the Western Piedmont geologic provinces (Fig. 3). The Scottsville basin is underlain by Triassic sandstones, siltstones, and conglomerates, and in places intruded by several Jurassic diabase dikes (Bailey et al., 2014). It is less well studied than the larger Culpeper and Dan River basins, and consequently, less is known about its history (Quinlan, 2012).

The goal of this research project is to conduct a paleomagnetic analysis of rocks in both the Scottsville basin and use that information to gain understanding of its geologic and magnetic history (Fig. 4 and 5). Preliminary work in the Scottsville basin suggests the rocks may have experienced re-magnetization after their deposition and crystallization (Bailey, pers. comm., 2015). If the paleomagnetic signatures of these rocks represent depositional remanence or thermoremanence, can their age be better estimated by correlating their paleomagnetic pole with those of previous studies? Alternatively, if these signatures represent post-deposition or post-crystallization magnetism, is there evidence to suggest what process is responsible for the magnetic overprinting? This research is important because it will build on recent work in an understudied area of Virginia during the most recent active period in its tectonic history. Furthermore, paleomagnetism of Mesozoic rocks across North America have yielded conflicting paleopoles, and this paleomagnetic analysis will add data to this inconsistency.

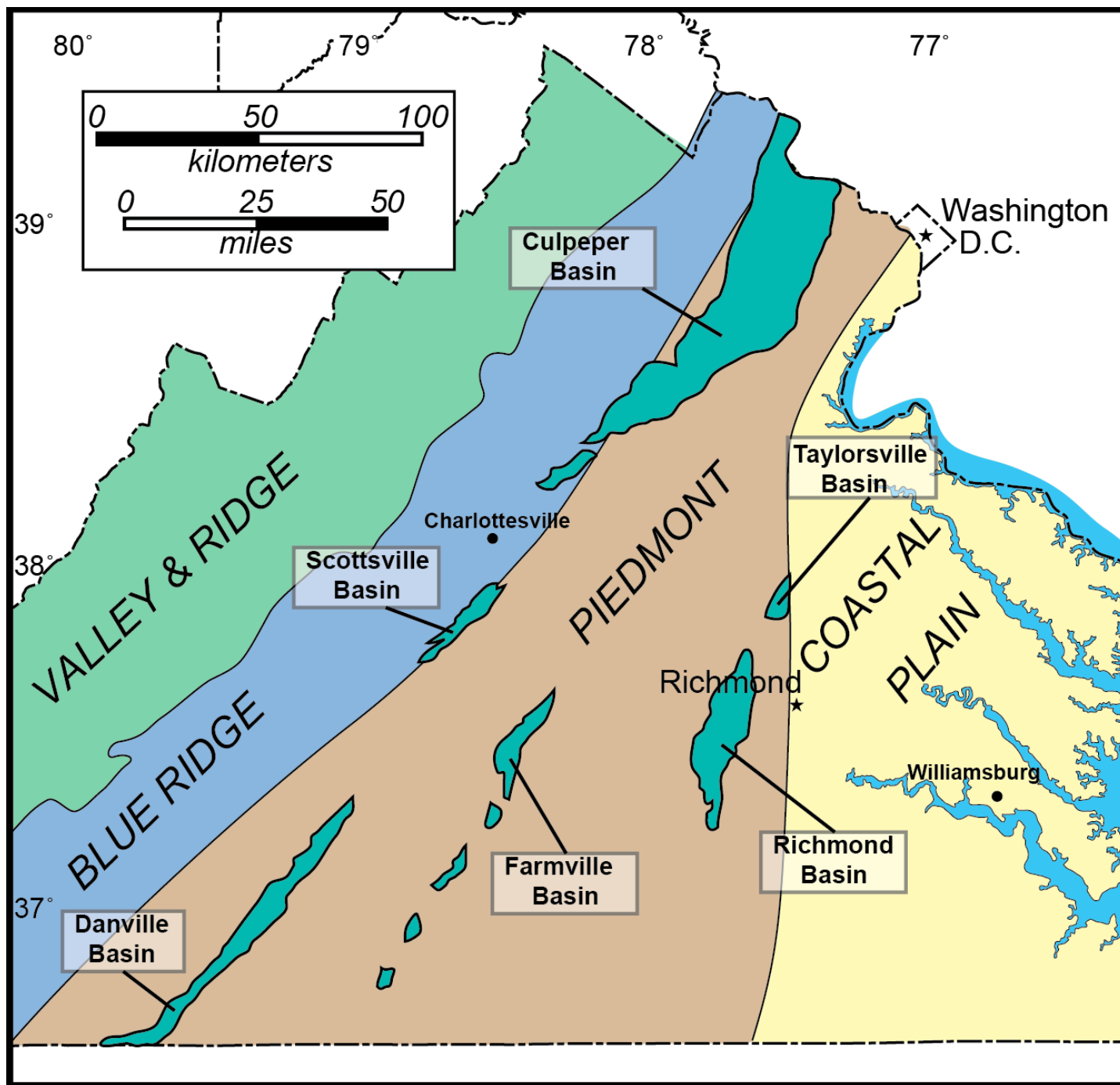


Figure 3 – Regional map of the state of Virginia, including the physiographic provinces and the exposed Mesozoic rift basins (shown in teal). The Scottsville basin is labelled (Modified from Bailey).

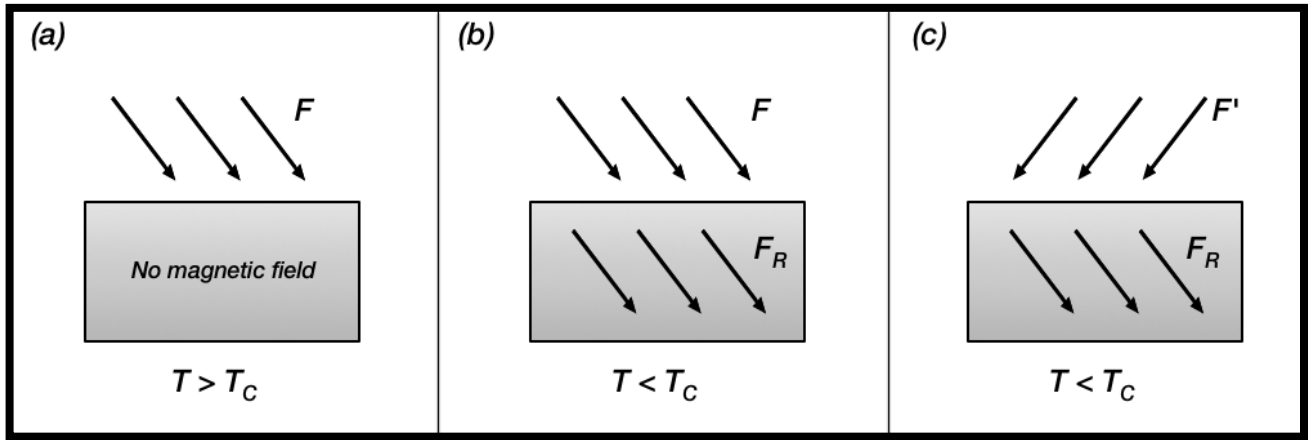


Figure 4 - Schematic explanation of thermoremanent magnetization. (a) When a rock with ferromagnetic minerals is at a temperature (T) above its Curie temperature (T_C), it cannot retain a magnetic field. (b) When that rock is cooled below its Curie temperature, it gains a remanent magnetic field (F_R) oriented parallel to Earth's magnetic field (F) at that location. (c) The rock retains this remanent magnetism even when exposed to a different magnetic field (F').

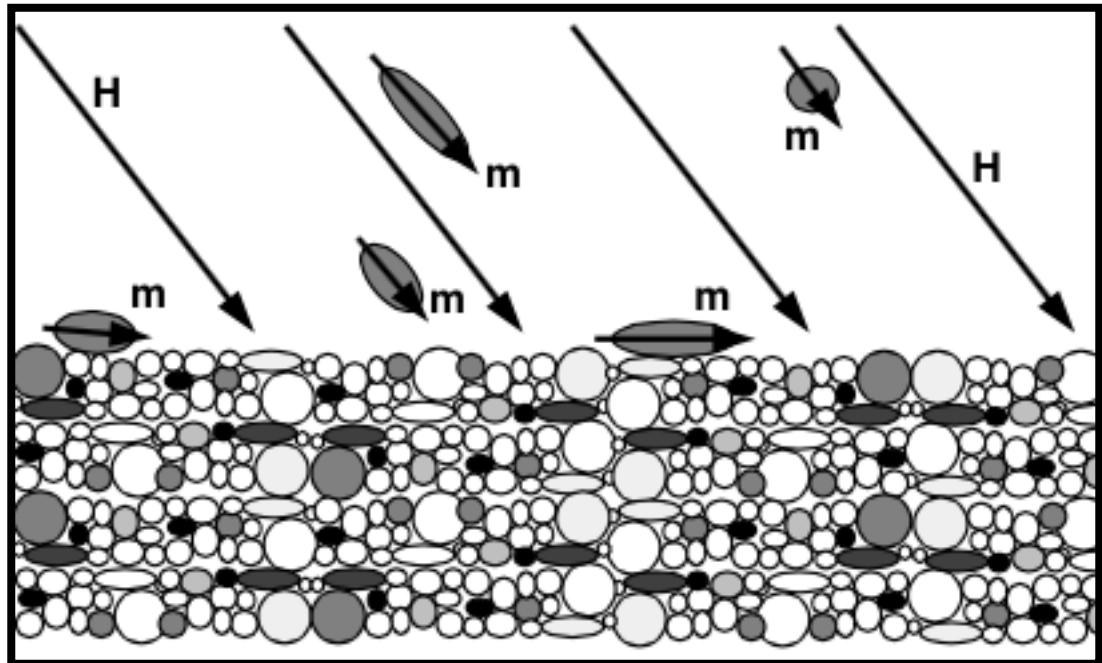


Figure 5 - Schematic explanation of detrital remanent magnetization. When ferromagnetic grains with magnetic moment (m) settle during deposition, they tend to wobble and align with Earth's magnetic field (H). During diagenesis, these grains form a sedimentary rock with a remanent field in the same approximate orientation as Earth's magnetic field (Modified from Butler, 1992).

Background:

Paleomagnetism

In 1912, Alfred Wegener developed the theory of continental drift, a concept that was staunchly opposed by many at that time, including the public and the scientific communities (Cox and Hart, 1986; Butler, 1992). Although Wegener and others provided substantial evidence to support this hypothesis, the theory of plate tectonics did not gain traction until the 1960s, when isotopic dating and paleomagnetism allowed geologists to quantify the ages and movements of Earth's plates (Cox and Hart, 1986). These advances in geochronology and geophysics helped transition our understanding of Earth from relatively static to a dynamic system. Today, paleomagnetism allows geologists to determine the paleolatitude of ancient continents (Kent and Olsen, 1997), the rotation of entire terranes (Kent and Witte, 1993), the rate of seafloor spreading (Cox and Hart, 1986), and large-scale tectonic history (Metelkin et al., 2010). Consequently, paleomagnetic analysis is a powerful tool, and is invaluable in answering many geologic questions.

Previous research has been done to calculate the Late Triassic/Early Jurassic paleopole of North America. Samples from the eastern North American Mesozoic rift basins, including the Danville and Newark basins, suggest a mean paleopole location of 56.3° N, 94.3° E (Kent and Olsen, 1997; Kent et al., 1995; Kent and Witte, 1993). However, paleomagnetic analyses of samples from the southwestern United States suggest a paleopole of ~60° N, ~65° E and anomalously high paleolatitudes for eastern North America (Molina-Garza et al., 1995). This discrepancy has been recently attributed to a large-scale clockwise rotation (10-15°) of the Colorado Plateau (Kodama

et al., 1994). Paleomagnetic analysis of the Scottsville basin has not been attempted, and this project will increase resolution of North American paleopole calculations, as well as help determine an age of the basin by comparing results to the Apparent Polar Wander Path of North America during the Mesozoic.

Geologic Setting:

The history of the eastern North American Mesozoic rift basins began during the late Paleozoic Era, when Africa and North America collided during the Alleghanian Orogeny and formed the supercontinent Pangea. The resulting suite of basement rocks underlies many of the basins across the region (Withjack et al., 1998). During the Middle Triassic, extensional stress led to the rifting and eventual breakup of Pangea. This extension generated a series of grabens and half-grabens bounded by NE-SW striking normal faults (Withjack et al., 1998), and clastic sedimentary rocks were deposited in a variety of terrestrial environments (Olsen, 1978). At the Triassic-Jurassic boundary (ca. 200 Ma), increased magmatic activity drove the intrusion of basaltic dikes and sills in a large area known as the Central Atlantic Magmatic Province (CAMP) (Dooley and Smith, 1982; Marzoli et al., 1999, 2011). This package of Triassic and Jurassic aged terrestrial sedimentary rocks is collectively known as the Newark Supergroup (Olsen 1978, Weems and Olsen, 1997).

The Scottsville basin has an area of $\sim 110 \text{ km}^2$ and is located approximately 25 km southwest of Charlottesville, Virginia (Fig. 6). The basin is a half-graben bound on the northwestern margin by a normal fault, and unconformably contacts phyllitic Piedmont rocks on its southeastern margin (Bailey et al., 2014). Sedimentary rocks in the basin range in grain size from boulder and pebble conglomerates (Fig. 7a) to arkosic sandstone

and siltstones (Kingery, 1954; Roberts, 1928) (Fig. 7b). The sandstones and siltstones are predominantly reddish-brown, suggesting the presence of iron-oxide minerals like hematite. Furthermore, these materials were primarily sourced from the Proterozoic rocks of the Blue Ridge west of the basin. Like in other Mesozoic basins, the sedimentary rocks in the Scottsville basin are thought to be Triassic in age, however the lack of fossils poorly constrains this age estimate (Bailey et al., 2014). Jurassic (~200 Ma) diabase dikes strike NNW and crosscut the Triassic sedimentary strata (Fig. 7c). These intrusions have a similar orientation to Mesozoic-aged fractures in the basin, which suggests the extensional stress field responsible for the dike emplacement was similar to that which caused the fractures (Quinlan, 2012).

To discern whether the Scottsville basin's geometry can be discerned in gravity station data taken throughout the Blue Ridge and Piedmont physiographic provinces by Johnson (1977) were compiled into a preliminary Bouguer anomaly contour map of the Scottsville basin region (Fig. 8). Steep gravity gradients are present from the Blue Ridge mountains to the NW margin of the basin, and also from the SE margin of the basin throughout the Piedmont. A relatively weak gravitational gradient is present throughout the basin, which indicates that the relative homogeneity in rock density expected in a sedimentary basin is present in the gravitational data.

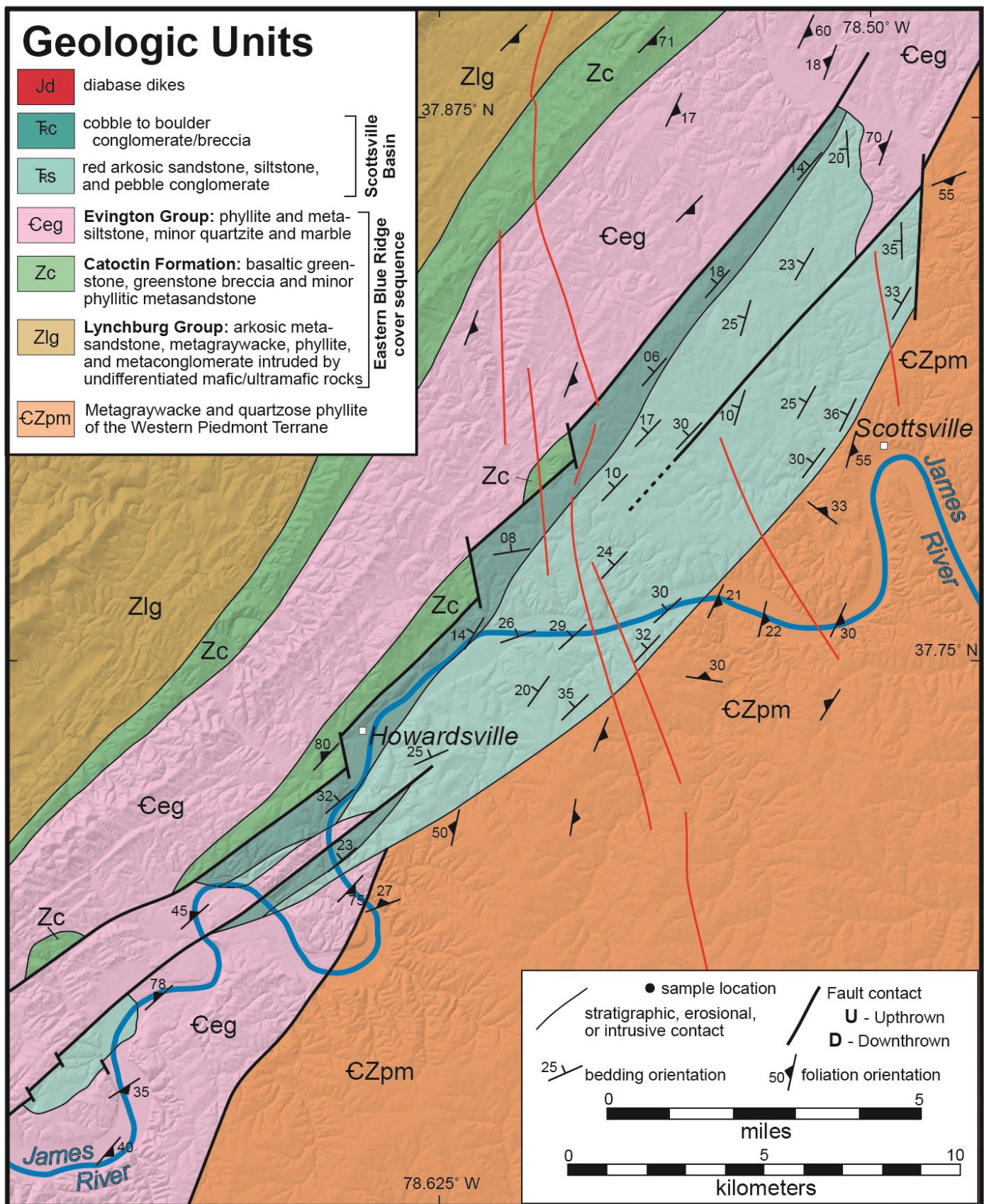


Figure 6 – Generalized geologic map of the Scottsville basin and surrounding areas (Modified from Bailey et al., 2014).



Figure 7a – Outcrop picture of a typical conglomerate in the Scottsville basin (Photo by Bailey, 2014).

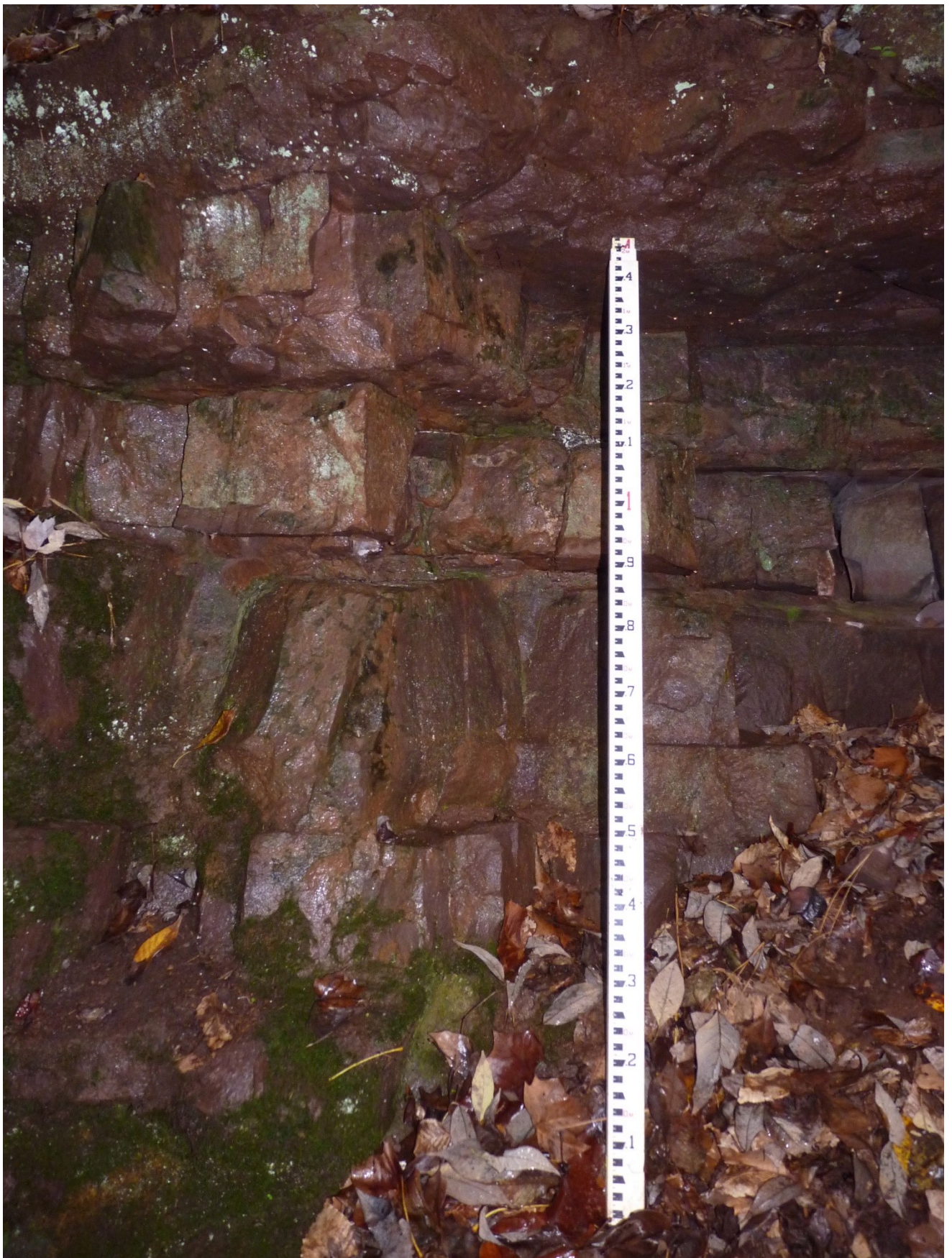


Figure 7b – Outcrop picture of a red sandstone in the Scottsville basin (Photo by Bailey, 2014).



Figure 7c – Picture of hand sample of Jurassic diabase in the Scottsville basin.

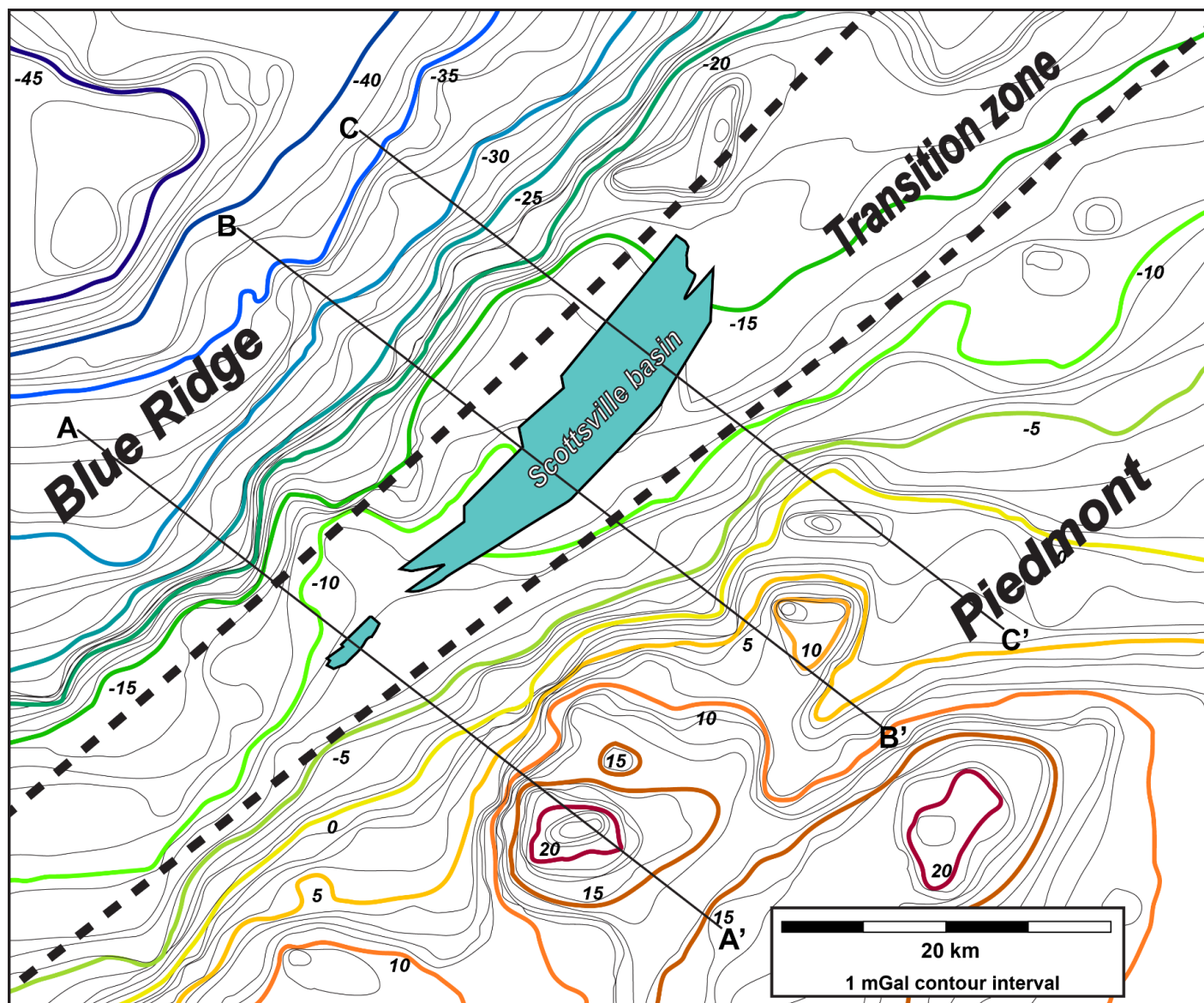


Figure 8a – Bouguer anomaly gravity contour map of the Scottsville basin region contoured around data taken by Johnson (1977).

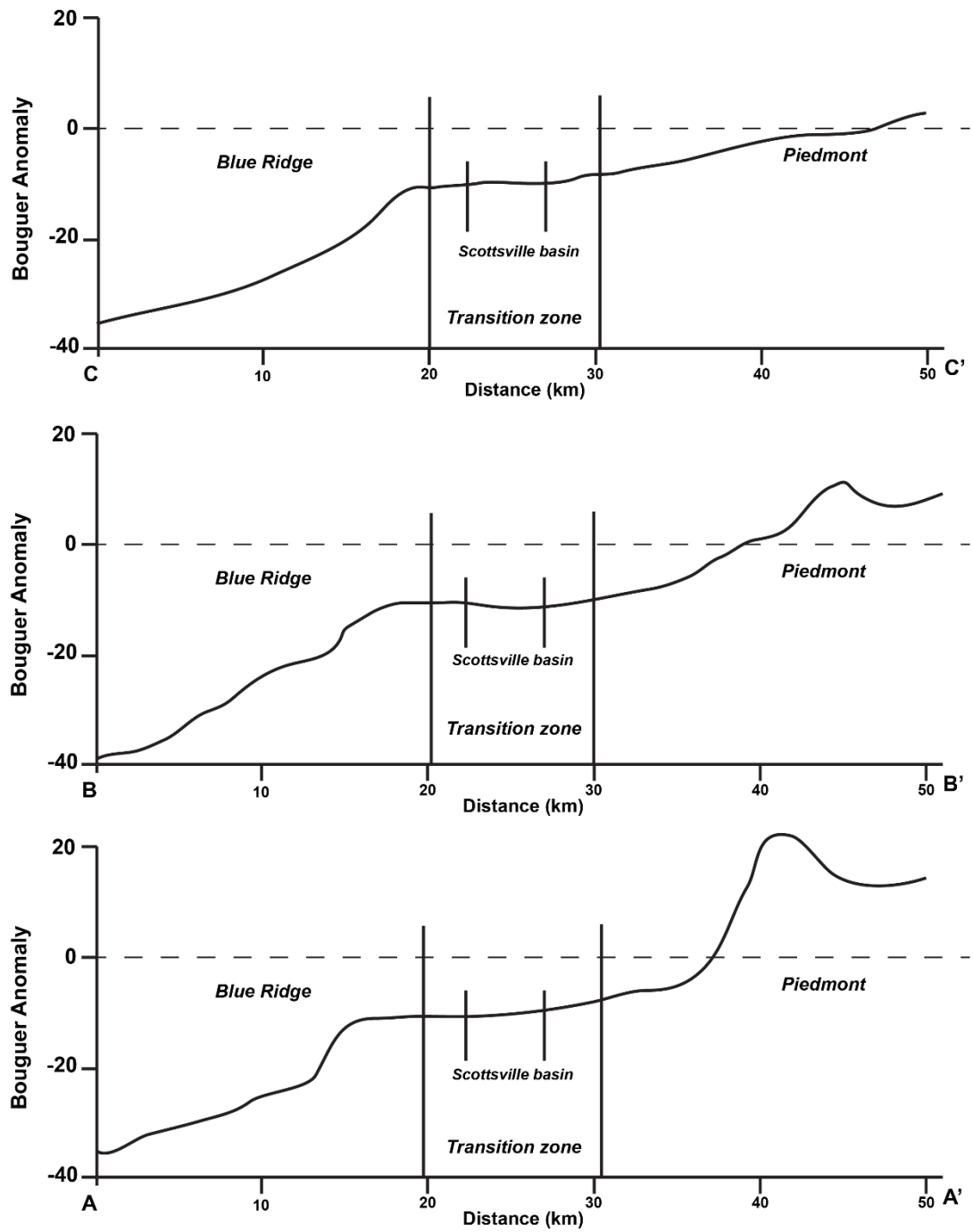


Figure 8b – Interpretive gravity anomaly cross-sections taken from the gravity contour map, showing strong gravity gradients in the Blue Ridge and Piedmont, and a low gravity gradient across the Scottsville basin

Methods:

Field Work:

To conduct a paleomagnetic analysis, one must first collect samples from the desired study location. Three trips to the Scottsville basin were made in 2015 to collect samples of siltstone, diabase, conglomerate, and hornfels samples in and around the James River. Sampled locations were collected across the basin and ranged from the town of Howardsville to the eastward margin of the basin near the town of Scottsville. In addition to collecting rock samples, GPS measurements and structural measurements were made at each location. Noting the *in situ* orientation of the sampled rocks is vitally important, for remanent magnetism is non-trivially directional. Recording the orientation of each rock core before removing them from the outcrop allows accurately constrained measurements of the inclination and declination of their remanent magnetic moments.

The first two trips focused on collecting large oriented block samples of siltstone, diabase, and hornfels, from which oriented cores could later be drilled at State University of New York Geneseo. The third field trip was a collaboration with Dr. Scott Giorgis and SUNY Geneseo students to collect data both for this project and for Dr. Giorgis' Introduction to Geophysics class. On that trip, two gasoline-powered diamond-bit drills were used to directly drill oriented cores of conglomerate and diabase at each outcrop (Fig. 9). In total, 16 block samples were collected from 8 different locations on the first two field trips, and 45 drill cores were collected from 3 different locations on the third trip.



Figure 9 - Drill cores of diabase (right) and fine sandstone (left) from the Scottsville basin with a quarter for scale (picture by Chuck Bailey).

Lab Work:

As The College of William & Mary does not have the equipment to perform paleomagnetic analysis, the samples were taken to SUNY Geneseo. In October, 30 oriented cores drilled from three of the oriented block samples of siltstones were analyzed. First, each core was run through the AGICO JR-6A dual speed spinner magnetometer (Fig. 10a) to measure its remanent magnetic moment in three orientations. After the first measurement, each core was run through the Sapphire Instruments SI-4 alternating field demagnetizer (Fig. 10b) to destroy a portion of its remanent magnetic field in each of the three measured orientations. Generally, high-coercivity (easy to destroy) components of the magnetic field are acquired post-deposition, while low-coercivity (harder to destroy) components represent a depositional signal. The demagnetization preferentially annihilates the high-coercivity components, leaving the low-coercivity components. This process was repeated for 15 different levels of demagnetization, ranging from 2-200 milliTeslas, for a total of 16 measurements of the magnetic moment for each core. After every core's magnetic signature was measured, the raw data were processed using a MatLab script written by Dr. Giorgis. This script calculated an inclination and declination of the remanent magnetic field, and statistical parameters for each core.

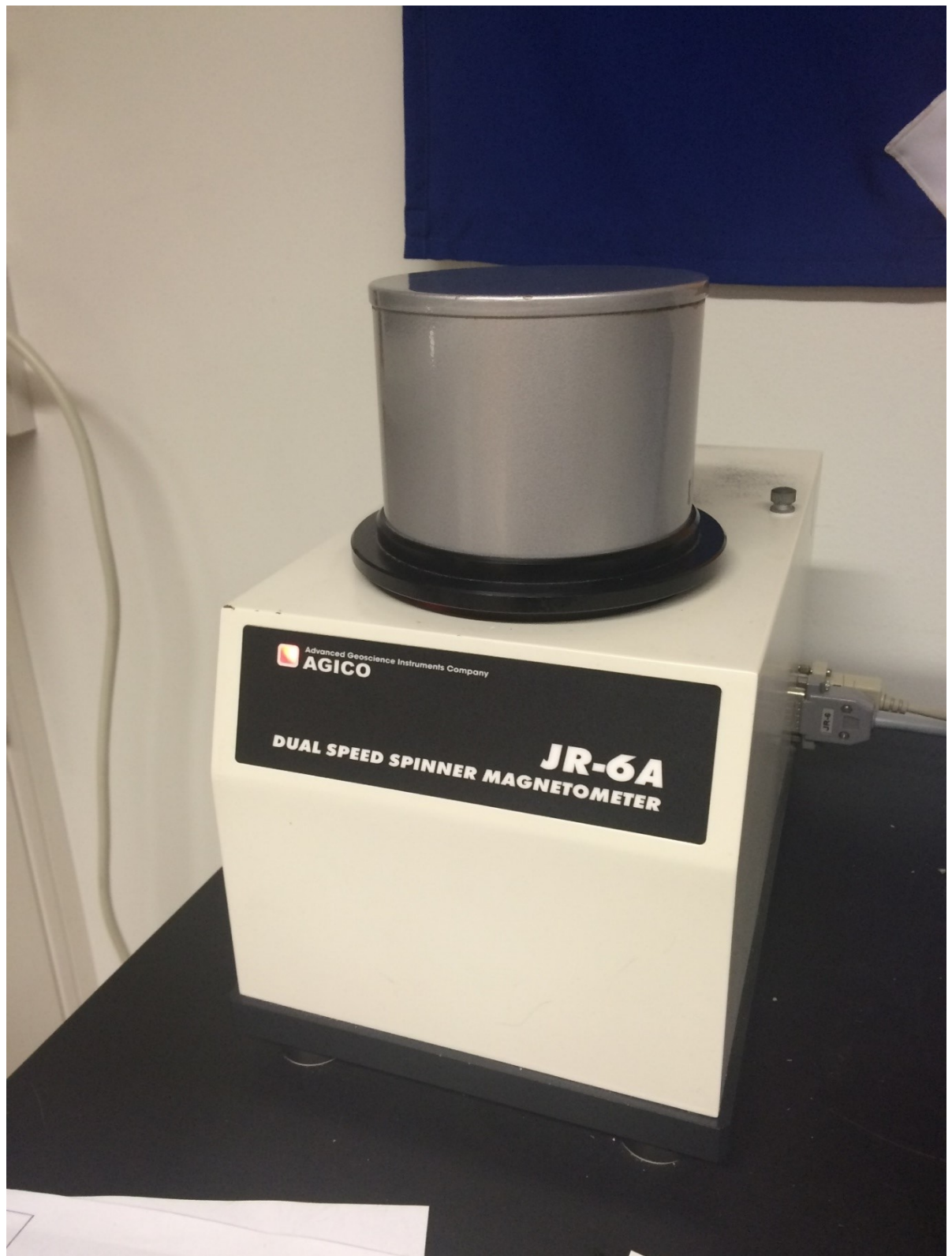


Figure 10a - AGICO JR-6A dual speed spinner magnetometer used to measure the magnetization of each core sample in three orientations.



Figure 10b - Sapphire Instruments SI-4 alternating field demagnetizer used to demagnetize each core sample at 15 stages of demagnetization ranging from 2 to 200 mT.

Results:

Paleomagnetic analyses were conducted for seven samples from the data collected in 2015, and compiled with data collected in 2012, yielded 12 individual paleomagnetic analyses from locations across the Scottsville Basin (Fig. 11). These data included six siltstone analyses, four diabase analyses, and two conglomerate tests, as well as a fold test of the siltstone samples. A summary of the following numeric results is presented in Table 1.

Siltstone:

Six samples (VA12-10, VA12-12, 15NK1A, 15NK2A, 15NK3A, and 15NK3B) were taken from fine sandstone/siltstones across the Scottsville basin and the Midway Mills sub-basin (Fig. 11). Cores from VA12-10 and VA12-12 were drilled *in situ* and the rest were taken as oriented block samples and later drilled in the lab at SUNY Geneseo. A mean inclination and declination averaged from 7-14 cores was calculated for each sample. In general, the siltstone results are consistent and closely scattered (Fig. 12). All samples fall beneath the cutoff for significance ($\alpha_{95} < \sim 15$) and four have very small 95% confidence intervals (α_{95} values less than 10), perhaps surprisingly so, given the inconsistency when conducting paleomagnetic analysis on sedimentary rocks. The majority of samples (VA12-10, VA12-12, 15NK1A, and 15NK3B) have mean tilt-corrected declinations between $\sim 325^\circ$ and $\sim 0^\circ$ and mean tilt-corrected inclinations between $\sim 20^\circ$ and $\sim 30^\circ$. Sample 15NK2A has a mean declination approximately $\sim 180^\circ$ displaced from the aforementioned majority, and a mean inclination of 4.9° (-21.1° before tilt-correction), which may indicate that the layer that contained 15NK2A was deposited during a period of reversed polarity.

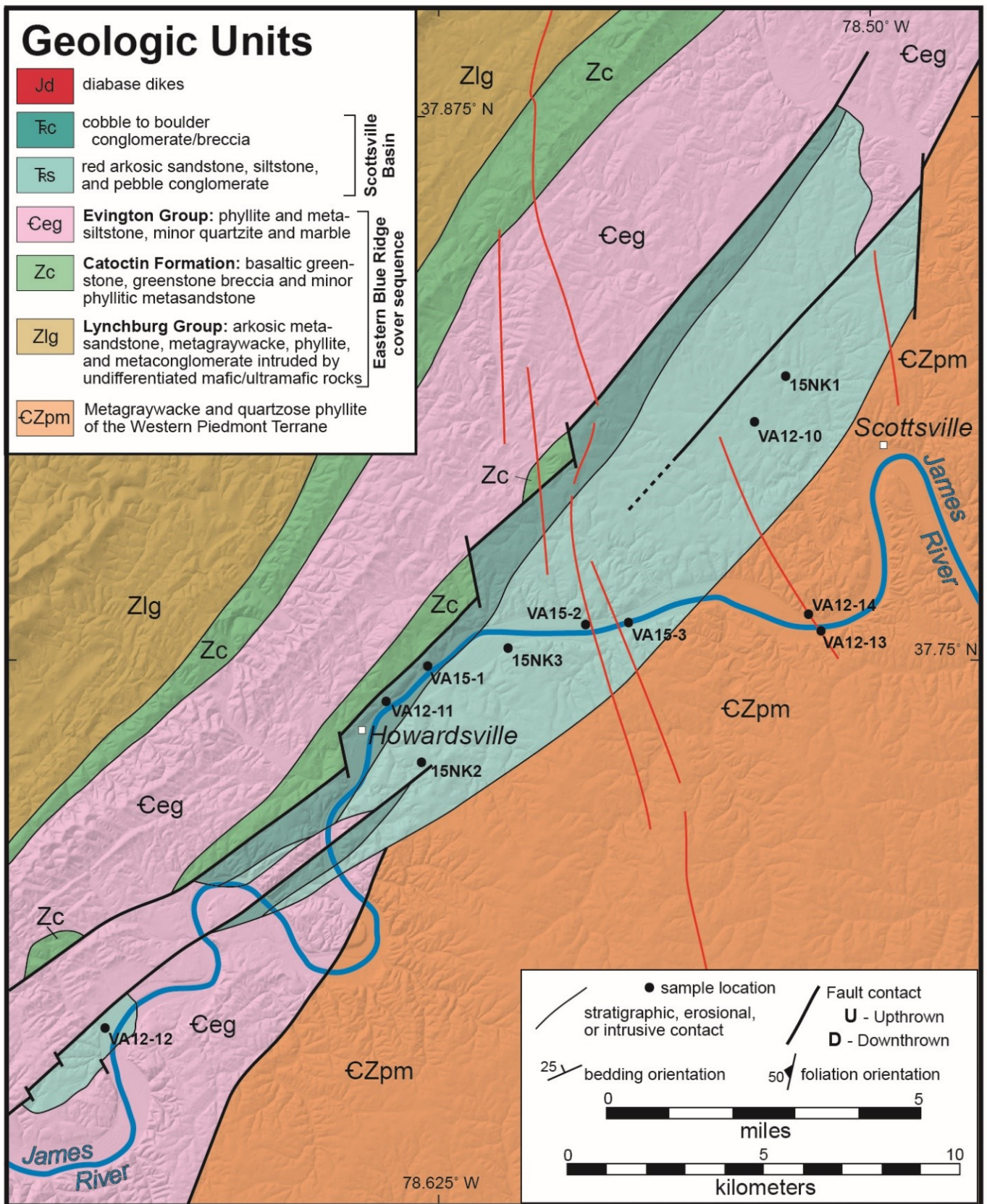


Figure 11 – Geologic map of the Scottsville basin showing locations of the sample locations used for paleomagnetic analysis (Modified from Bailey et al., 2014).

TABLE 1. SUMMARY OF PALEOMAGNETIC DATA FROM THE SCOTTSVILLE BASIN

Site	Rock type	N/No	α_{95}	k	D (° <i>in situ</i>)	I (° <i>in situ</i>)	Dc (° tilt corr.)	Ic (° tilt corr.)	Latitude (° North)	Longitude (° West)
VA12-10	Siltstone	14/14	9.8	15	357.9	44.4	335	28	37.80463	78.51600
VA12-12	Siltstone	9/10	5.8	115	001.6	25.0	359.8	19.5	37.65925	78.72263
15NK1A	Siltstone	10/10	6.8	42.4	338.5	46.9	322.9	19.8	37.81027	78.51213
15NK2A	Siltstone	9/10	12.5	13.9	159.5	-21.1	159.7	4.9	37.72562	78.63281
15NK3A	Siltstone	13/15	7.4	27.5	100.4	48.8	89.6	78.5	37.75511	78.59839
15NK3B	Siltstone	7/10	11.6	20.7	342	37.6	329	18.2	37.75511	78.59839
VA12-05 & 11	Conglomerate	12/12	(Conglomerate Test; R = 4.862; Ro = 5.591)						37.73858	78.64222
VA15-1	Conglomerate	16/16	(Conglomerate Test; R = 11.780; Ro = 6.456)						37.74641	78.62738
VA12-13	Diabase	7/7	25.8	4.21	358.5	-10.1	NA	NA	37.75810	78.51413
VA12-14	Diabase	6/8	5.4	111	016.3	32.4	NA	NA	37.75822	78.51463
VA15-2	Diabase	6/17	12	22.6	347.0	55.6	NA	NA	37.75704	78.57947
VA15-3	Diabase	6/12	15.3	13.9	185.2	-45.0	NA	NA	37.75773	78.57080

N/No – number of samples used vs. number of samples collected; α_{95} – 95% confidence interval around the estimated mean direction; k – Fisher precision parameter (Fisher, 1953); D – *in situ* declination; I – *in situ* inclination; Dc - tilt corrected declination; Ic - tilt corrected inclination; Latitude and longitude of the sampling locality.

Table 1 – Paleomagnetic analysis data from the Scottsville basin.

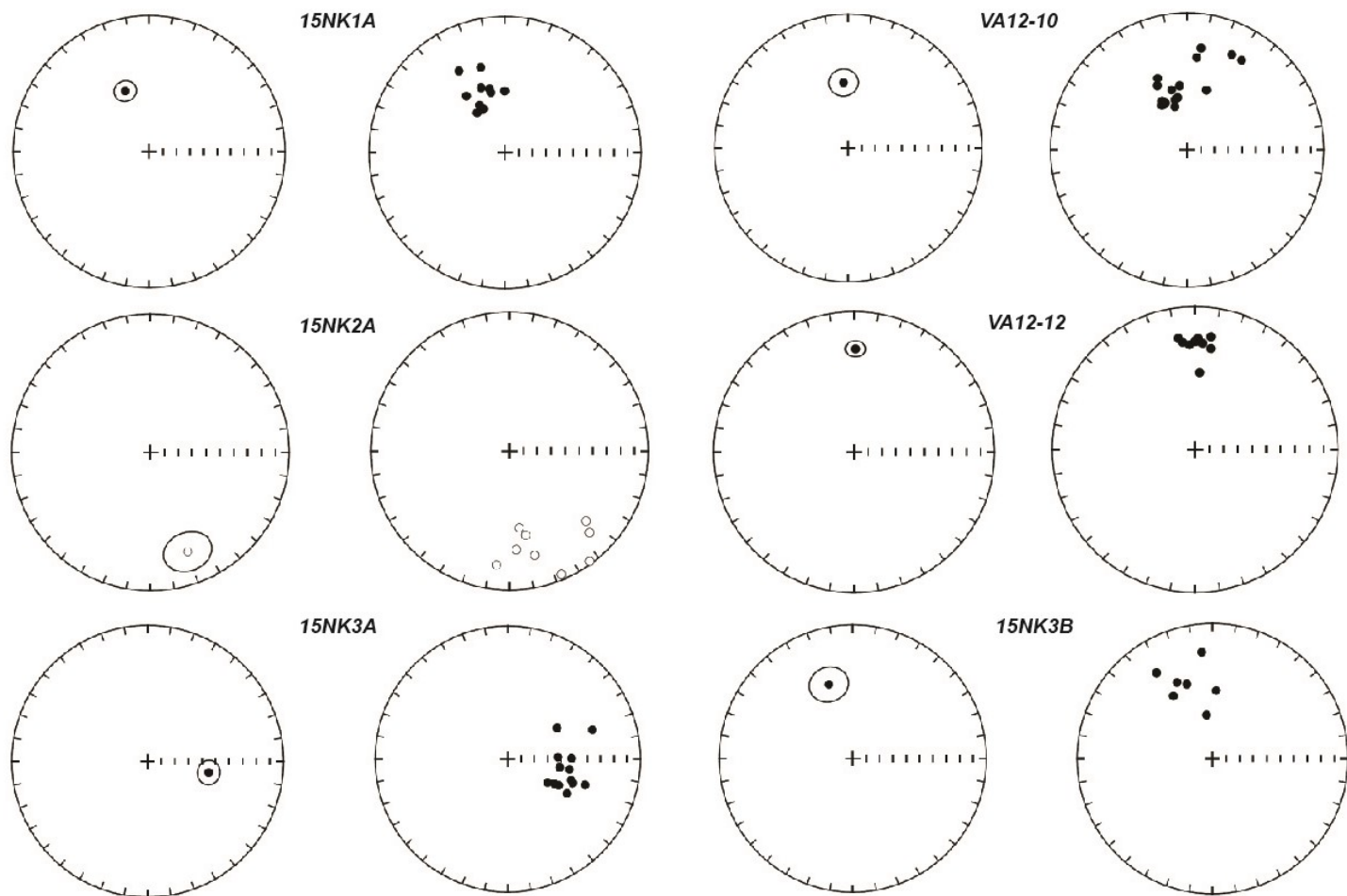


Figure 12 – Stereographic representation of paleomagnetic data from siltstones in the Scottsville basin, showing mean inclination and declination (left) and inclination and declination of each core (right) for each sample location.

Conglomerate test:

Two samples (VA12-11 and VA15-1) were taken from conglomerates in the western part of the Scottsville basin (Fig. 11). Cores were drilled from individual clasts in the conglomerate outcrops *in situ*. Unlike the siltstone and diabase samples, the conglomerate samples were analyzed by using the conglomerate test (Fig. 13). Rather than attempting to measure a mean inclination and declination of each sample, the conglomerate test aims to measure whether the orientation of the remanent magnetic field of each core in a sample is random at a 95% confidence interval. If a conglomerate has a depositional magnetic signature, each core's magnetic field should have a random orientation ($R < R_0$), as clasts with their own magnetic fields are deposited in a random orientation. If a conglomerate has experienced remagnetization, however, the orientation of the magnetic fields of each core should not be random ($R > R_0$), as magnetization would be acquired post-deposition. VA12-11 just passes the conglomerate test, which means that the magnetic fields of each sampled clast are oriented randomly ($R = 4.862$, $R_0 = 5.591$). However, VA15-1 fails the conglomerate test badly ($R = 11.780$, $R_0 = 6.456$), meaning the sampled clasts have non-random magnetic field orientations at the 95% confidence level, suggesting post-depositional remagnetization.

Fold test:

As the *in situ* orientation of the sampled siltstones was tilted, a fold test was calculated to determine whether the siltstone data are best aligned *in situ* or in the depositional orientation (horizontally bedded). As shown in Figure 14, the siltstones fail the fold test; they are most closely aligned *in situ*, and tilting them back to the horizontal

results in further spreading the data. This suggests that magnetization took place after the siltstones were tilted to their current orientation.

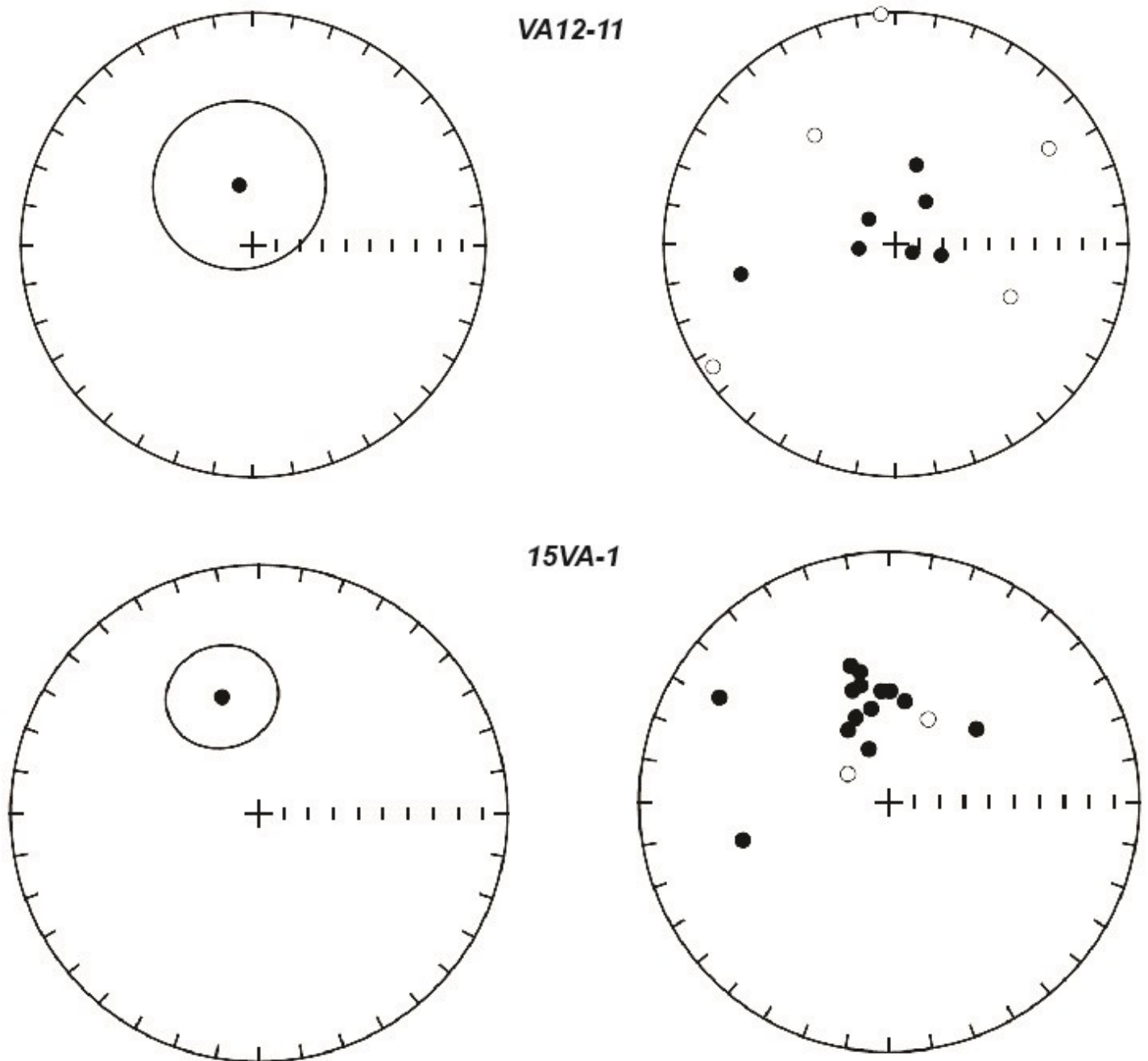


Figure 13 – Stereographic representation of paleomagnetic data from conglomerates in the Scottsville basin, showing mean inclination and declination (left) and inclination and declination of each core (right) for each sample location.

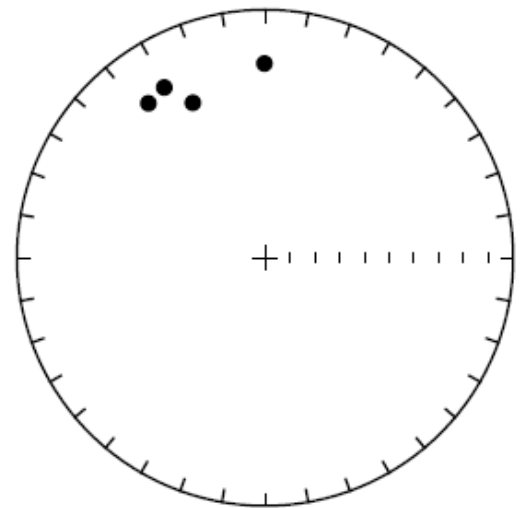
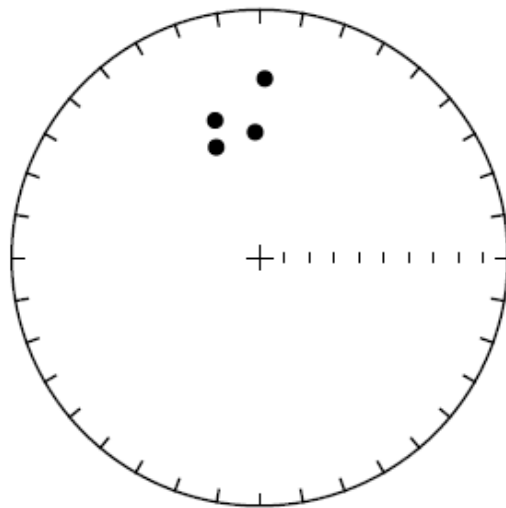
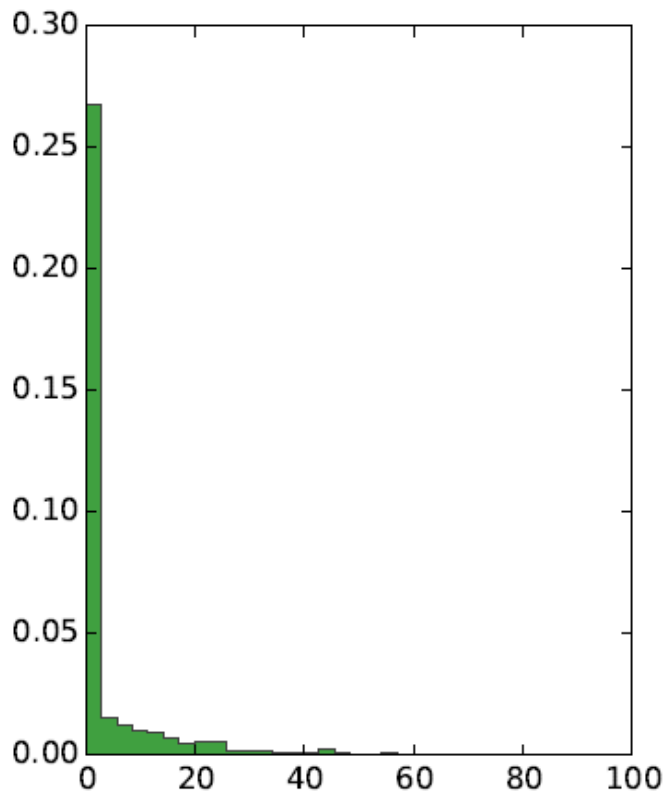


Figure 14 – Data from fold test of siltstones in the Scottsville basin. Top graph shows measure of closeness compared with percentage that samples are rotated back to horizontal. Bottom stereographs show *in situ* orientations (left) and tilt-corrected orientations (right), showing closer data *in situ*.

Diabase:

Four samples (VA12-13, VA12-14, 15NK2, and 15NK3) were drilled from diabase dikes in the Scottsville basin along the James River between Howardsville and Scottsville. A mean inclination and declination averaged from 6-7 cores was calculated for each sample. Unlike the siltstone, which yielded relatively consistent and narrow 95% confidence intervals, the diabase samples yielded a much larger variation in both mean inclination and declination and α_{95} values (Fig. 15). Two samples (VA12-14 and VA15-2) fell beneath the cutoff for significance ($\alpha_{95} < \sim 15$), however, VA15-3 fell just above that cutoff ($\alpha_{95} = 15.3$) and VA12-13 had by far the largest confidence interval ($\alpha_{95} = 25.8$) and fell well outside the margin for significance. VA15-3 had a mean declination of 185.2° , while the other three samples had mean declinations between $\sim 350^\circ$ and $\sim 015^\circ$. Mean inclinations ranged greatly from -45.0° to 55.6° . This observation is surprising, as sedimentary rocks generally yield less precise paleomagnetic data than mafic igneous rocks, in which ferromagnetic minerals are typically abundant. In these data collected in Scottsville, the opposite result is present: the siltstones produce more precise results than the diabase. As no bedding planes were present in the sampled dikes, *in situ* orientation was assumed to be the same as the dikes' original orientation ($\sim 340^\circ$ to $\sim 90^\circ$), and no tilt-corrected declination or inclination was calculated.

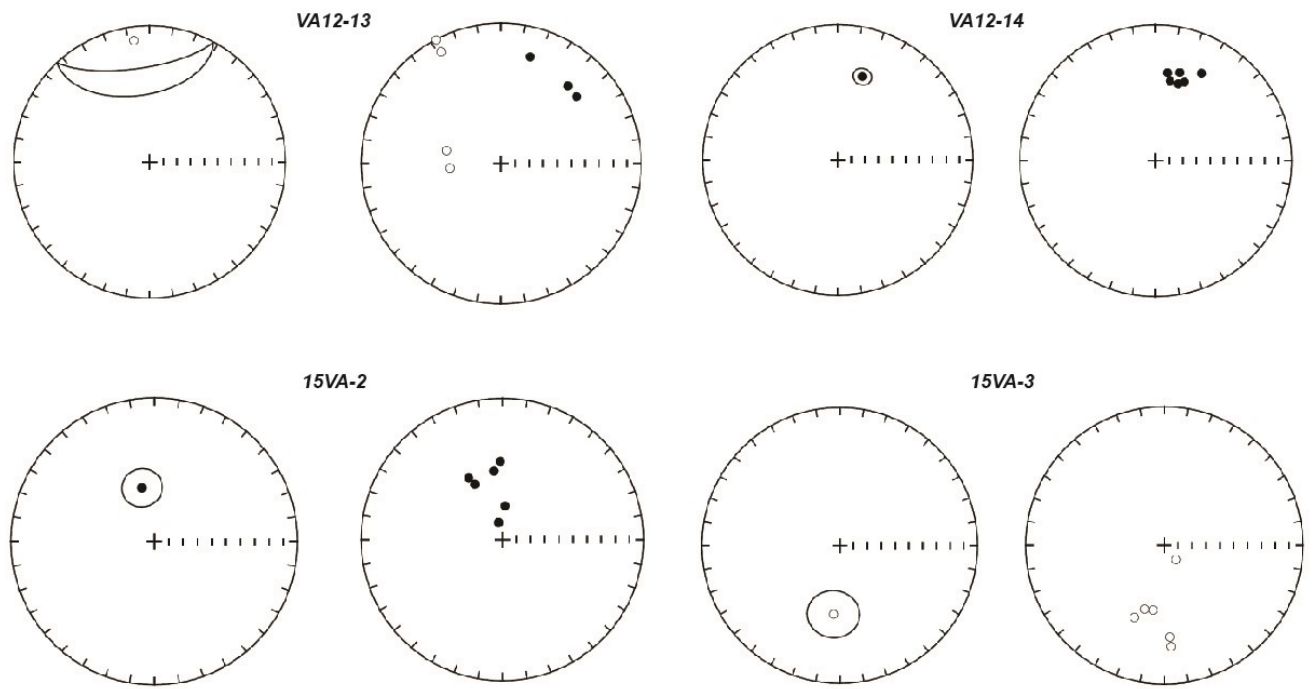


Figure 15 – Stereographic representation of paleomagnetic data from conglomerates in the Scottsville basin, showing mean inclination and declination (left) and inclination and declination of each core (right) for each sample location.

Discussion:

The aforementioned paleomagnetic data of rocks in the Scottsville basin suggest some key points about the history of the basin. First, analysis of the sampled conglomerates indicated non-random magnetic field orientations of individual clasts at the 95% confidence level, thereby failing the conglomerate test. This suggests a post-deposition remagnetization which generated a preferred orientation of the magnetic fields of individual clasts. Furthermore, a fold test of the siltstones indicated that the mean magnetic fields of each siltstone outcrop were best aligned in their *in situ* orientation (tilted roughly 20° to the NW), rather than rotated back to horizontal (their likely depositional orientation). This suggests that the magnetization of the siltstone was acquired post-deposition and post-deformation. The conglomerate test and fold test both indicate a similar point: *the magnetization of the sedimentary rocks in the Scottsville basin is not a primary depositional magnetization*. Consequently, as these tests suggest remagnetization took place after deposition, the magnetization age of the siltstones and conglomerates would likely not represent the depositional age of those rocks. However, determining when remagnetization occurred is still important in understanding the geologic history of the Scottsville basin.

Using paleomagnetic data to calculate ages of rocks can be used in a number of different ways. Correlating magnetic reversals in cores of rock with an established chronostratigraphy has been used in a number of studies of Mesozoic rift basins similar to the Scottsville basin such as the Danville and Taylorsville basins in Virginia, and the Newark basin in New Jersey (Kent and Olsen, 1997; LeTourneau, 2003; Olsen et al., 1996). However, a different method was used in this research project in the Scottsville

basin. First, mean virtual geomagnetic poles (VGPs) and confidence intervals were calculated from mean orientations of the magnetic fields from the diabase and siltstone outcrops using a transformation to spherical coordinates. Next, those VGPs were superimposed over an apparent polar wander path (APWP) of North America ranging from the beginning of the Mesozoic Era to the present day. Finally, the time interval of the APWP overlapped by the confidence interval of each VGP represents a range of likely magnetization ages (Fig. 16).

The siltstone VGP is located at $\sim 67^\circ$ N $\sim 135^\circ$ E and overlaps the APWP between 160 and 180 Ma, suggesting a Middle Jurassic magnetization age. This contrasts the Late Triassic magnetization ages of other Virginia Mesozoic rift basins, such as the Danville and Taylorsville basins described by Kent and Olsen (1997) and LeTourneau (2003) respectively. Given the hypothesis that the Scottsville basin was deposited during the Late Triassic, this Jurassic magnetization age supports the notion of a post-deposition and post-deformation remagnetization of the siltstones suggested by the results of the fold and conglomerate tests.

The diabase VGP is distinctly different than the siltstone VGP. The latitude and longitude of the VGP is $\sim 77^\circ$ N $\sim 80^\circ$ E. The cone of confidence is much larger than that of the siltstones, and overlaps the AWPW between 165 and ~ 205 Ma, and also from ~ 70 Ma to the present location of the magnetic pole. Unfortunately, unlike the siltstones, these data suggest a large range of magnetization ages, including the crystallization age of the diabase (~ 198 -200 Ma) and the magnetization ages of the siltstones (160-180 Ma). Furthermore, the orientation of the diabase dikes in the field likely represent their original crystallization orientation, so no fold test was conducted. The lack of statistical tests like

the fold or conglomerate test, as well as the large range of possible magnetization ages given by the VGP and APWP, makes it difficult to assign a probable magnetization age or discern whether the magnetization of the diabase represents a primary thermoremanent magnetization or a secondary remagnetization.

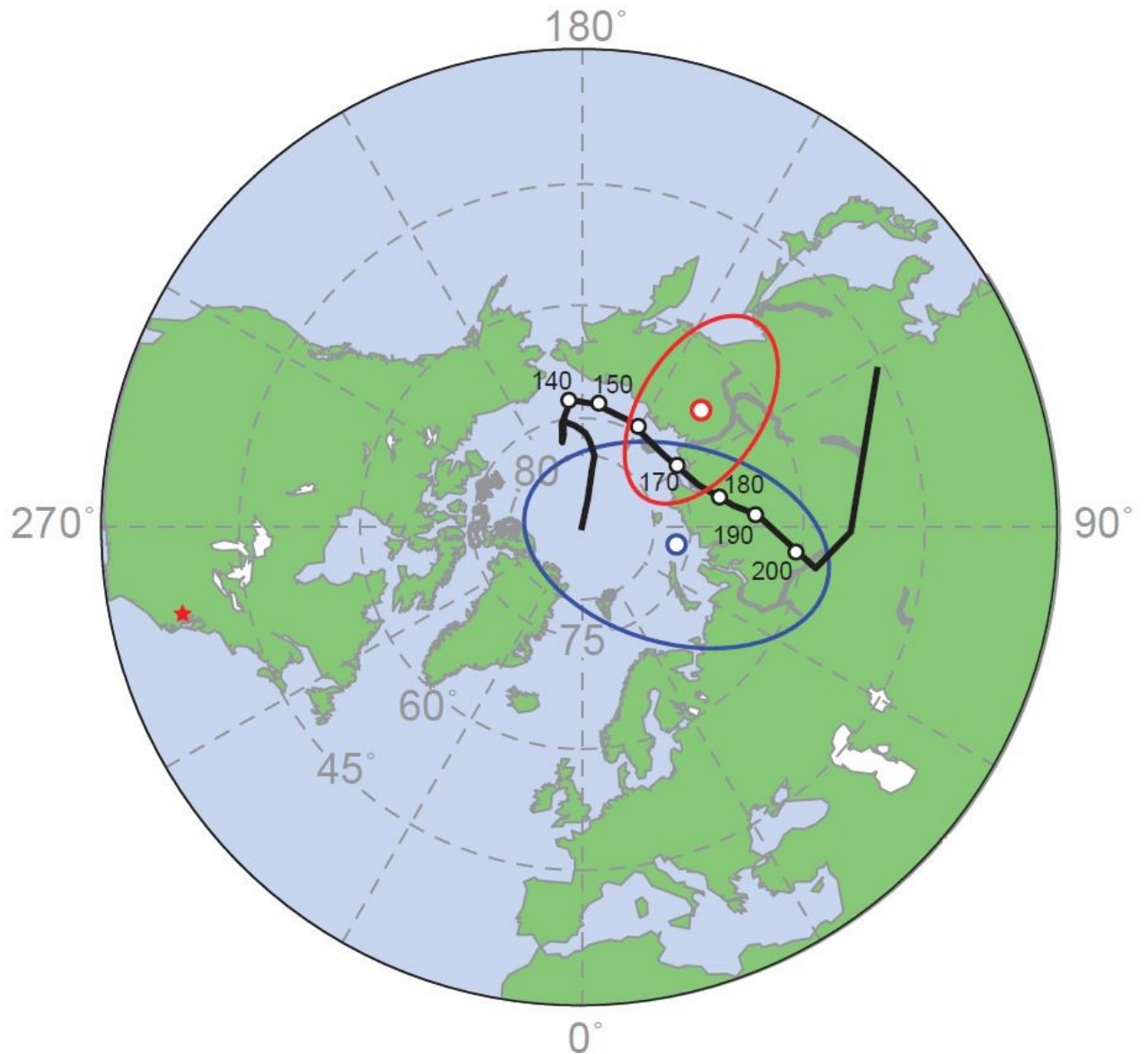


Figure 16 – Polar view of the North American apparent polar wander path (APWP) in black, with mean siltstone virtual geomagnetic pole (red) and mean diabase virtual geomagnetic pole (blue) superimposed over it. Location of the Scottsville basin starred in red.

One possibility to explain the remagnetization observed in the siltstone paleomagnetic data is a chemical remanent magnetization. Butler (1992) explains that a secondary chemical remanent magnetization can be acquired in red sedimentary rocks tens of millions of years after deposition when detrital magnetite is altered to hematite, effectively masking the primary depositional remanent magnetization. One hypothesis regarding the cause of a chemical remanent magnetization is chemical alteration driven by fluid intrusion.

Hydrothermal fluid intrusion during rifting has been proposed in other Mesozoic rift basins during the Jurassic. For example, Steckler and others (1993) used fission-track analysis to hypothesize a (100-250°) hydrothermal fluid convection system in the Newark basin that persisted during the Middle Jurassic (175-178 Ma) associated with the late stages of Pangea breakup and early seafloor spreading of the Atlantic Ocean. Furthermore, Witte and Kent (1991) identified a remagnetization event in the Newark basin that temporally coincided with that hydrothermal system. It is plausible that a similar hydrothermal event affected rocks in the Scottsville basin, leading to chemical alteration and the post-deposition and post-deformation remagnetization suggested by these data.

Future Work:

As noted earlier, the Scottsville basin has received little research attention in the ~90 years since its description by Roberts in 1928. However, Quinlan (2012) and Bailey (2014) have conducted two studies in the Scottsville basin focusing primarily on the structural geology of the rocks in the basin. Furthermore, research by other William & Mary students focusing on the stress regimes in the Blue Ridge-Piedmont transition zone,

including the Scottsville basin, is ongoing. Future work in the Scottsville basin could build on these previous and ongoing research projects. Another new research avenue could include detailed petrographic analysis of rocks in the basin to better understand the compositional similarities and differences between the Scottsville basin and other Mesozoic rift basins. Additionally, field geophysical studies, including gravity and magnetic surveys, could be conducted in the basin and synthesized with existing gravity and aeromagnetic data to better characterize the basin geometry. Finally, these research possibilities could be extended to other understudied Mesozoic rift basins in Virginia, for example, the Barbourville basin located ~50 km NE of the Scottsville basin.

Conclusion:

The Scottsville basin is one of the many Mesozoic rift basins exposed along the Atlantic margin of North America generated during the rifting of Pangea. Although little research had been done in the basin since its identification in the early 20th century, recent work at the College of William & Mary has increased the understanding of the geology and history of the basin. The paleomagnetic data presented in this thesis show that the rocks in the Scottsville basin experienced a Middle Jurassic remagnetization, suggesting that the paleomagnetic history of the Scottsville basin is different than other similar basins across eastern North America. This distinctiveness, in addition to the unique widespread presence of red bed sandstones and siltstones, differentiates the Scottsville basin from other more-studied basins in Virginia. Understanding the geologic and tectonic history is important in understanding the history of the Virginia Blue Ridge-Piedmont transition zone, and more broadly, of eastern North America as a whole.

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